The Space Segment

- A satellite communications system can be broadly divided into two segments—a ground segment and a space segment.

- **<u>The space segment</u>** will obviously include :

➢ the satellites

➢ but it also includes the ground facilities needed to keep the satellites operational, these being referred to as the tracking, telemetry, and command (TT&C) facilities.

- **<u>The equipment carried aboard the satellite also can be classified according to function</u>**:
- ➢ The **payload** refers to the equipment used to provide the service for which the satellite has been launched.
- ➢ The **bus** refers not only to the vehicle which carries the payload but also to the various subsystems which provide the power, attitude control, orbital control, thermal control, and command and telemetry functions required to service the payload.
- In a communications satellite, the equipment which provides the connecting link between the satellite's transmit and receive antennas is referred to as the transponder

The Power Supply

- The primary electrical power for operating the electronic equipment is obtained from solar cells. Individual cells can generate only small amounts of power, and therefore, arrays of cells in series-parallel connection are required.
- The HS 376 spacecraft is a spin-stabilized spacecraft (the gyroscopic effect of the spin is used for mechanical orientational stability.
- During the launch sequence, the outer cylinder is telescoped over the inner one, to reduce the overall length. Only the outer panel generates electrical power during this phase.
- In geostationary orbit the telescoped panel is fully extended so that both are exposed to sunlight.
- At the beginning of life, the panels produce 940 W dc power, which may drop to 760 W at the end of 10 years. During eclipse, power is provided by two nickel-cadmium (Ni-Cd) long-life batteries, which will deliver 830 W.

- HS 601 satellite :
- Higher powers can be achieved with solar panels arranged in the form of rectangular solar sails. Solar sails must be folded during the launch phase and extended when in geostationary orbit
- the solar sails are folded up on each side, and when fully extended, they stretch to 67 ft (20.42 m) from tip to tip.
- The full complement of solar cells is exposed to the sunlight, and the sails are arranged to rotate to track the sun, so they are capable of greater power output than cylindrical arrays having a comparable number of cells.
- The HS 601 can be designed to provide dc power from 2 to 6 kW.

- In order to maintain service during an eclipse, storage batteries must be provided. Ni-Cd batteries continue to be used, as shown in the Hughes HS 376 satellite, but developments in nickel-hydrogen (Ni-H2) batteries offer significant improvement in power-weight ratio. Ni-H2 batteries are used in the Hughes HS 601 .

Attitude Control

- The attitude of a satellite refers to its orientation in space. Much of the equipment carried aboard a satellite is there for the purpose of controlling its attitude. Attitude control is necessary, for example, to ensure that directional antennas point in the proper directions.
- In the case of earth environmental satellites, the earth-sensing instruments must cover the required regions of the earth, which also requires attitude control.
- A number of forces, referred to as **disturbance torques** ,can alter the attitude, some examples being the gravitational fields of the earth and the moon, solar radiation, and meteorite impacts.

- the attitude-control process takes place aboard the satellite, but it is also possible for control signals to be transmitted from earth, based on attitude data obtained from the satellite.
- Also, where a shift in attitude is desired, an attitude maneuver is executed. The control signals needed to achieve this maneuver may be transmitted from an earth station.
- **Controlling torques may be generated in a number of ways:**

➢ Passive attitude control refers to the use of mechanisms which stabilize the satellite without putting a drain on the satellite's energy supplies; at most, infrequent use is made of these supplies, for example, when thruster jets are impulsed to provide corrective torque. Examples of passive attitude control are spin stabilization and gravity gradient stabilization.

- The other form of attitude control is active control. With active attitude control, there is no overall stabilizing torque present to resist the disturbance torques.

- Methods used to generate active control torques include momentum wheels, electromagnetic coils, and mass expulsion devices, such as gas jets and ion thrusters.
- The electromagnetic coil works on the principle that the earth's magnetic field exerts a torque on a current-carrying coil and that this torque can be controlled through control of the current. However, the method is of use only for satellites relatively close to the earth.

Station Keeping

- In addition to having its attitude controlled, it is important that a geostationary satellite be kept in its correct orbital slot.
- the equatorial ellipticity of the earth causes geostationary satellites to drift slowly along the orbit, to one of two stable points, at 75°E and 105°W.
- To counter this drift, an oppositely directed velocity component is imparted to the satellite by means of jets, which are pulsed once every 2 or 3 weeks.
- This results in the satellite drifting back through its nominal station position, coming to a stop, and recommencing the drift along the orbit until the jets are pulsed once again. These maneuvers are termed east-west station-keeping maneuvers.
- Satellites in the 6/4-GHz band must be kept within + or -0.1° of the designated longitude, and in the 14/12-GHz band, within + or -0.05°.

- Asatellite which is nominally geostationary also will drift in latitude, the main perturbing forces being the gravitational pull of the sun and the moon.

- These forces cause the inclination to change at a rate of about 0.85°/year. If left uncorrected, the drift would result in a cyclic change in the inclination, going from 0° to 14.67° in 26.6 years and back to zero, at which the cycle is repeated. To prevent the shift in inclination from exceeding specified limits, jets may be pulsed at the appropriate time to return the inclination to zero.

- Counteracting jets must be pulsed when the inclination is at zero to halt the change in inclination. These maneuvers are termed north-south station-keeping maneuvers, and they are much more expensive in fuel than are east-west station-keeping maneuvers.

- The north-south station-keeping tolerances are the same as those for east-west station keeping, 0.1°in the C band and 0.05° in the Ku band.

- Orbital correction is carried out by command from the TT&C earth station, which monitors the satellite position.

Thermal Control

- Satellites are subject to large thermal gradients, receiving the sun's radiation on one side while the other side faces into space. In addition, thermal radiation from the earth and the earth's albedo, which is the fraction of the radiation falling on earth which is reflected, can be significant for low-altitude earth-orbiting satellites, although it is negligible for geostationary satellites.

- Equipment in the satellite also generates heat which has to be removed. The most important consideration is that the satellite's equipment should operate as nearly as possible in a stable temperature environment.

- Thermal blankets and shields may be used to provide insulation. Radiation mirrors are often used to remove heat from the communications payload .

TT&C Subsystem

- The TT&C subsystem performs several routine functions aboard the spacecraft.
- The telemetry, or telemetering, function could be interpreted as measurement at a distance. Specifically, it refers to the overall operation of generating an electrical signal proportional to the quantity being measured and encoding and transmitting this to a distant station, which for the satellite is one of the earth stations.
- Certain frequencies have been designated by international agreement for satellite telemetry transmissions.
- Telemetry and command may be thought of as complementary functions.

- The telemetry subsystem transmits information about the satellite to the earth station, while the command subsystem receives command signals from the earth station, often in response to telemetered information.
- The command subsystem demodulates and, if necessary, decodes the command signals and routes these to the appropriate equipment needed to execute the necessary action.
- Tracking of the satellite is accomplished by having the satellite transmit beacon signals which are received at the TT&C earth stations.
- it is necessary to be able to track the satellite’s movement and send correction signals as required.

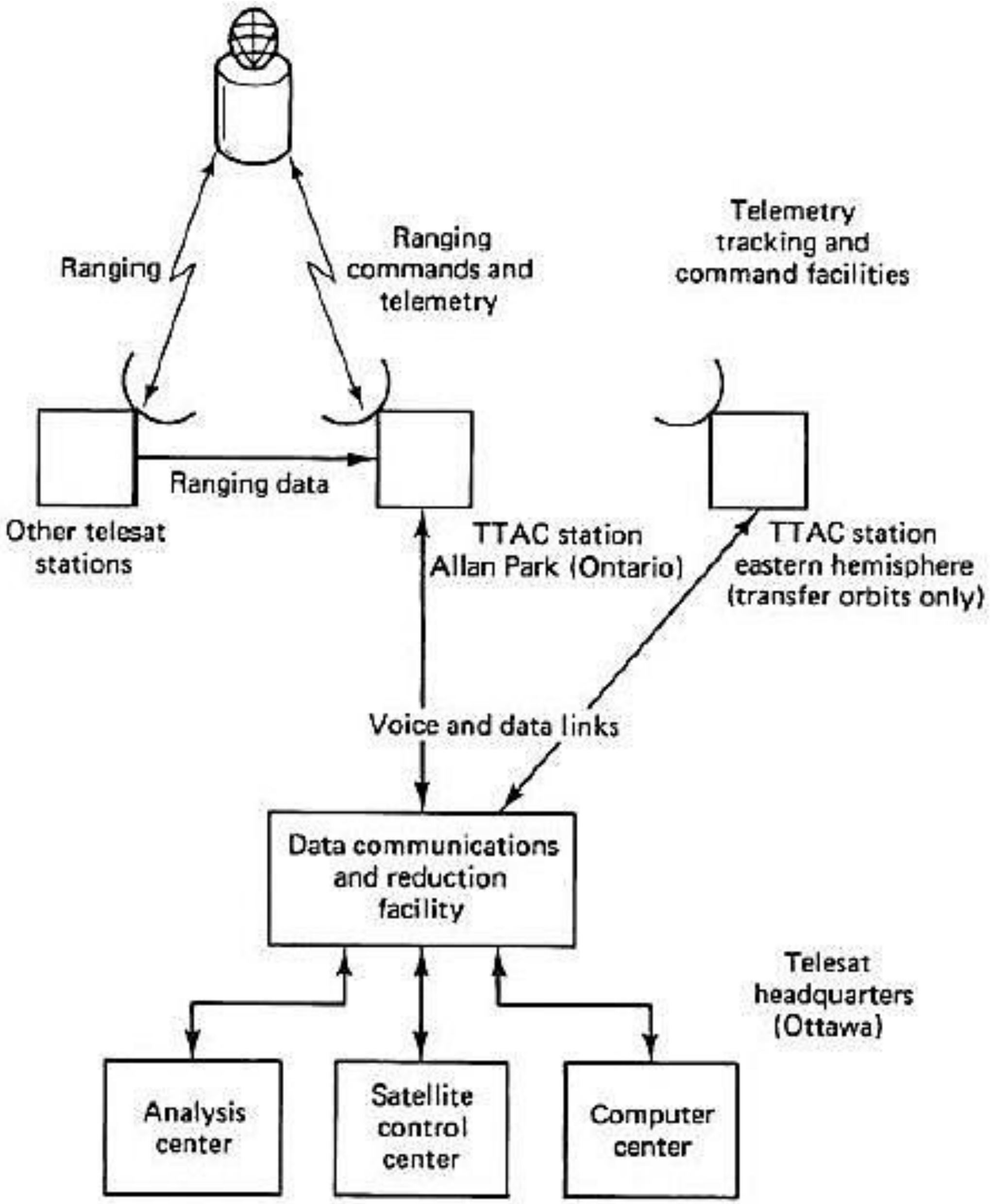

Figure 7.11 Satellite control system. (*Courtesy of Telesat Canada, 1983.*)

Transponders

- Atransponder is the series of interconnected units which forms a single communications channel between the receive and transmit antennas in a communications satellite. Some of the units utilized by a transponder in a given channel may be common to a number of transponders .
- The bandwidth allocated for C-band service is 500 MHz, and this is divided into subbands, one for each transponder.
- Atypical transponder bandwidth is 36 MHz, and allowing for a 4-MHz guardband between transponders, 12 such transponders can be accommodated in the 500-MHz bandwidth.
- By making use of polarization isolation, this number can be doubled. Polarization isolation refers to the fact that carriers, which may be on the same frequency but with opposite senses of polarization, can be isolated from one another by receiving antennas matched to the incoming polarization .

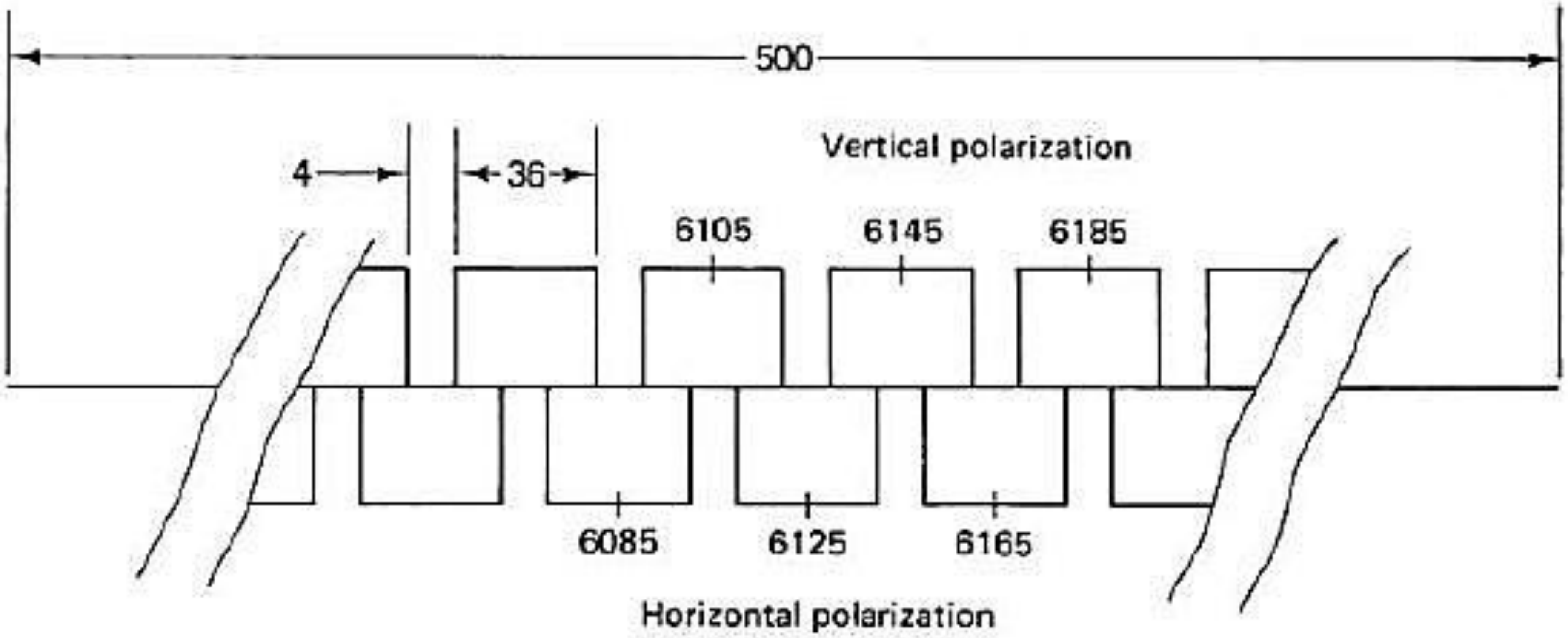

Figure 7.12 Section of an uplink frequency and polarization plan. Numbers refer to frequency in megahertz.

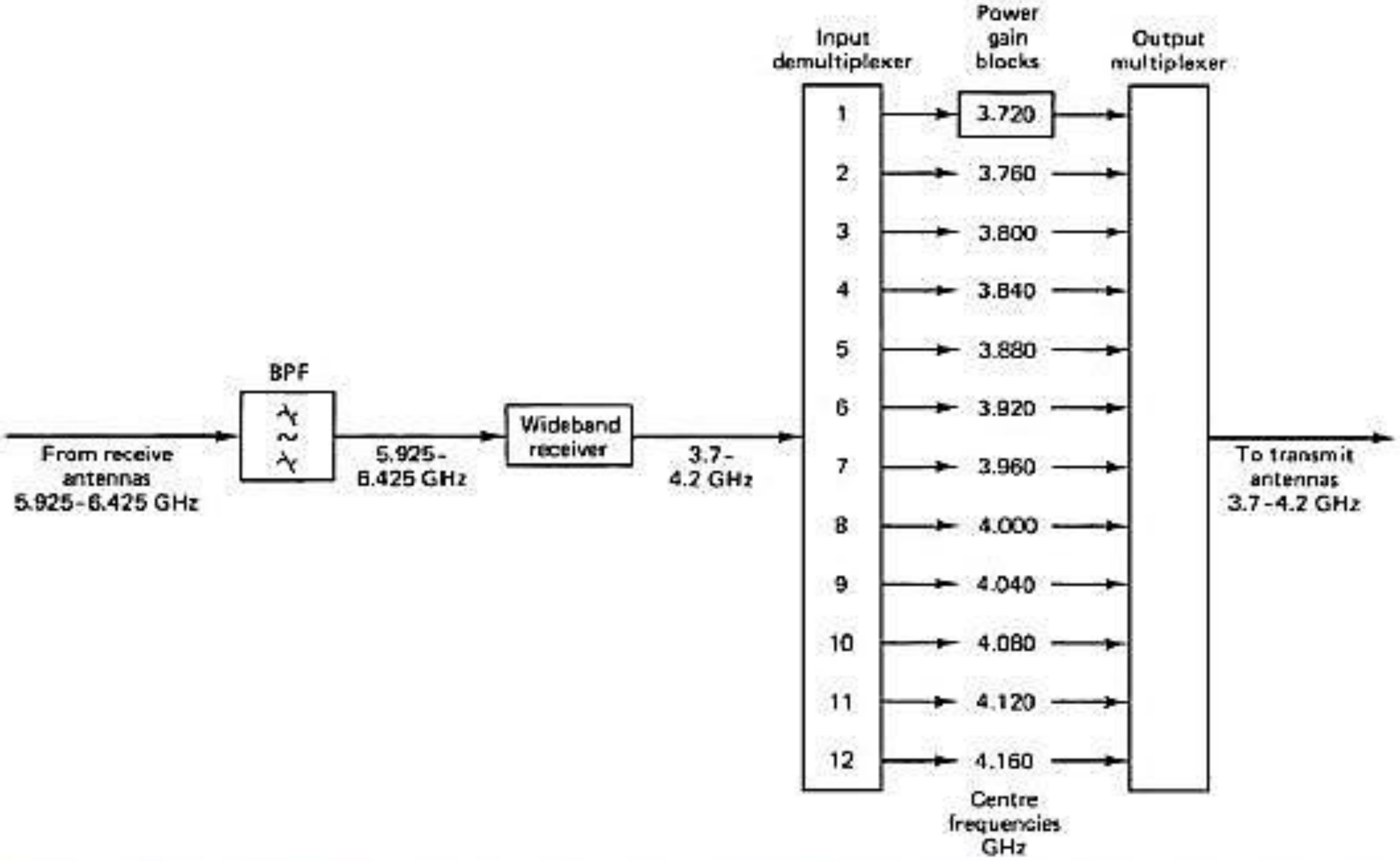

Figure 7.13 Satellite transponder channels. (*Courtesy of CCIR, CCIR Fixed Satellite Services Handbook, final draft 1984.*)

- The input filter passes the full 500-MHz band to the common receiver while rejecting out-of-band noise and interference such as might be caused by image signals.
- There will be many modulated carriers within this 500-MHz passband, and all of these are amplified and frequency converted in the common receiver.
- The frequency conversion shifts the carriers to the downlink frequency band, which is also 500 MHz wide, extending from 3.7 to 4.2 GHz. At this point the signals are channelized into frequency bands which represent the individual transponder bandwidths.

- The wideband receiver :

- A duplicate receiver is provided so that if one fails, the other is automatically switched in. The combination is referred to as a redundant receiver, meaning that although two are provided, only one is in use at a given time.

- The first stage in the receiver is a low-noise amplifier (LNA). This amplifier adds little noise to the carrier being amplified, and at the same time it provides sufficient amplification for the carrier to override the higher noise level present in the following mixer stage.

- The LNA feeds into a mixer stage, which also requires a local oscillator(LO) signal for the frequency-conversion process.

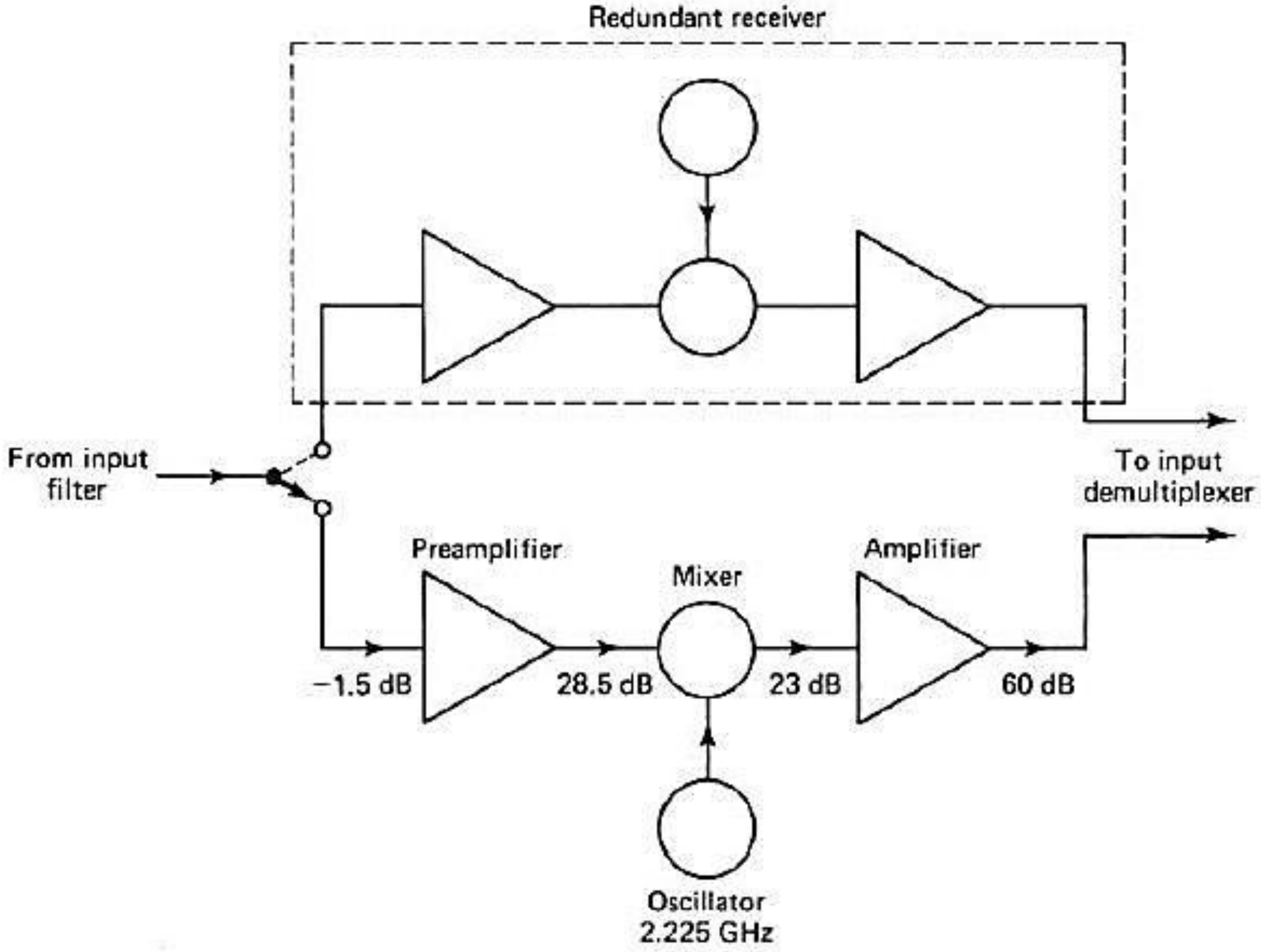

Figure 7.14 Satellite wideband receiver. (*Courtesy of CCIR, CCIR Fixed Satellite Services Handbook, final draft 1984.*)

The input demultiplexer

- The input demultiplexer separates the broadband input, covering the frequency range 3.7 to 4.2 GHz, into the transponder frequency channels.

- The channels are usually arranged in even-numbered and odd-numbered groups. This provides greater frequency separation between adjacent channels in a group, which reduces adjacent channel interference.

- The output from the receiver is fed to a power splitter, which in turn feeds the two separate chains of circulators. The full broadband signal is transmitted along each chain, and the channelizing is achieved by means of channel filters connected to each circulator.

- Each filter has a bandwidth of 36 MHz and is tuned to the appropriate center frequency.

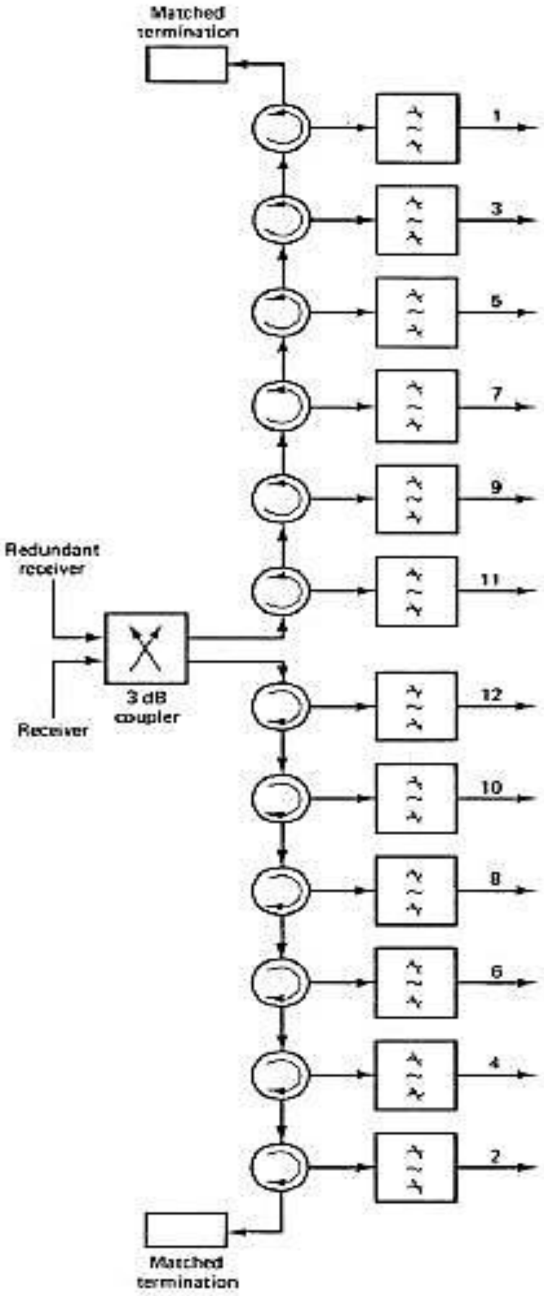

Figure 7.15 Input demultiplexer. (*Courtesy of CCIR, CCIR Fixed Satellite Services Handbook, final draft 1984.*)

The power amplifier

- A separate power amplifier provides the output power for each transponder channel.
- Traveling-wave tube amplifiers (TWTAs) are widely used in transponders to provide the final output power required to the transmit antenna .